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ASSESSMENT OF IRRIGATION WATER QUALITY AND SELECTED SOIL PARAMETERS AT MANKESSIM IRRIGATION SCHEME, GHANA

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Abstract: Irrigation has become very critical in acquiring an all year round crop production. The aim of the research work was to assess the irrigation water quality and selected soil parameters at the Mankessim irrigation scheme, which is used to irrigate all types of crops within Mankessim and its environs. The data of the study was collected from two sources, from water and soil samples. Water samples were collected from three different surface water sources within the scheme for both the dry and wet seasons. Nine (9) different samples were collected for each season, three (3) samples for each surface water source. Also, six (6) different soil samples were collected for each season. Soil samples were collected from an irrigated and non-irrigated farm lands. The results of the study indicated that water sources, that is from surface sources did not differ significantly from each other comparing the dry and wet seasons and that their chemical values were within the limits acceptable for irrigation and crop production. The concentrations (Na, Ca, Mg, EC and TDS) were fairly within the permissive limits for crop water use.

Keywords*: Irrigation water quality, Salinity, Total Dissolved Solids*

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INTRODUCTION

A drastic increase in irrigation activities was witnessed during the post –World War II and has contributed substantially to the massive growth in the agricultural production that enables humanity to feed its doubling population [1]. However, a distinction has to be made between the overall positive contribution of irrigation and water to agricultural productivity and economic welfare and a significant amount of misallocation and management of resources that have accompanied the expansion of irrigation. According to Khanom and Salehin [2], soil salinity is a normal hazard in many parts of coastal areas, affecting different uses of water including irrigation, drinking, household, fisheries, and functioning of the ecosystem. If there is any harmful chemical component, it can affect the irrigation system through wear and tear and the plant growth directly through toxicity or deficiency, or indirectly by altering plant availability of nutrients [3],[4], [5]. It must also be emphasized that irrigation systems which are the mechanisms that allow water to be diverted from its original place to be applied to the agricultural fields for supplementing water for crop growth and enhancing yields [6], could also be affected by soil water salinity. Irrigation water quality is related to its effects on soils and cultivated crops and its management [7]. High-quality crops need high-quality irrigation water keeping other inputs optimal. Haque [8] analyzed that the severity of the salinity problem in coastal areas increases with the desiccation of the soil. Salinity intrusion due to sea-level rise will decrease agricultural production through the unavailability of fresh water and soil degradation [9].

Increasing demands of food grain by ever increasing population has resulted in the over utilization of water resources. However, an appropriate evaluation of the water quality prior to its use in irrigation will help in arresting any harmful effect on plant productivity and ground water recharge. The issue of irrigation water quality is still not properly addressed. The fertility needs, irrigation system performance and longevity and how the water can be applied contribute to irrigation water quality. Crops cannot grow properly if the irrigation water is not of good quality.

Also, soil may lose its fertility if the irrigation water is highly saline. The productivity of farmers who use such water for irrigation will reduce. It is therefore important for the farmers to know the chemical composition of the irrigation water to enable the irrigation engineer to know the chemicals that might be affecting the irrigation system and the crop, and hence reducing their yield. Hence this study was conducted to assess the quality of water used for irrigation and to determine the levels of selected chemical properties of soils in irrigated and non-irrigated parts of the Mankessim irrigation scheme in the Central Region of Ghana.

MATERIALS AND METHODS

Study area

The water and soil samples as well as other related data collected were carried out over the period between December –March, 2018 (dry season) and from April – July, 2019 (wet season) in Mankessim (Fig. 1). The Mankessim irrigation scheme is located around latitude 5^{O} 18' - 5^{O} 20' N and longitude 1^{O} 02' - 1^{O} 04' W at Barfikrom (Mankessim) in the Mfantsiman district in the Central Region of Ghana.

The project has as head-works an earth dam constructed in 1978 and is designed for gravity and sprinkler irrigation systems. The Mankessim irrigation project is used by farmers within Mankessim and its environs for irrigations of their vegetables.

Figure 1. Map of Central region within which Mfantseman district is located

Climate of Mankessim

Mankessim has a tropical climate. The average temperature in Mankessim is 26.7℃. Precipitation here averages 1150 mm. The driest month is January, with 23 mm of rainfall. Most of the precipitation here falls in June, averaging 275 mm. The warmest month of the year is March, with an average temperature of 28.1℃. August is the coolest month, with temperatures averaging 24.4 ℃. The difference in precipitation between the driest month and the wettest month is 252 mm throughout the year while temperatures vary by 3.7 ℃.

Geography and Soil of Mfantseman Municipal District

Mankessim is within the Mfantseman Municipal which is located along the Atlantic coastline of the Central region of Ghana and extends from latitude 5^{O} to 5^{O}20' north of the equator and longitudes 0^{O}44' to 1^{O}11' west of the Greenwich Meridian, stretching for about 21 kilometers inland and constituting an area of 612 square kilometers. According to FAO [10] and Effland et al. [11] the area is characterized by Savannah ochrosols. Soils along the river banks and irrigated sites are loose clay. Some areas possess silt deposits. Loose fertile silty loam is found further from the river.

Vegetation type and topography of Mfantseman Municipal District

According to the Ministry of Food and Agriculture, Ghana, two major vegetation types are found. On the upland is the coastal shrub while the flood plains are characterized with grasses growing to a height of about two meters. Land is undulating and about 60 m above sea level. Major streams and rivers are Narkwa, Bruku, Ochi and Amisa.
Flood plain areas lie below 60 m above sea level.

Water samplings and analysis

Water sampling procedure and analysis
The water samples were collected from three surface water sources used by the farmers. The samples were collected in both the wet and dry seasons.

Three water samples each were collected from the surface water which was used for irrigating crops at three identified points within the catchment area and labelled as surface water 1, surface water 2 and surface water 3. The samples collected were kept in thoroughly washed containers and covered to avoid the contamination which might affect the analysis.
The samples were collected during the wet and dry seasons and were analyzed for pH (Using pH meter), Electrical Conductivity (using the EC meter), Sodium (using salinometer), Iron, Total Dissolved Solids, Total Suspended Solids, Nitrate, Calcium, and Magnesium.

Determination of Iron
For the determination of iron in the samples that were provided, Iron Cell Test Kit from Spectroquant in the Test Kit all the iron ions present in the samples were reduced to Fe^{2+} ions by ascorbic acid. In the presence of the medium thioglycolate, a purple complex was formed because Fe^{2+} react with a trizine derivative. The complex was determined photometrically by using UV-Vis spectrophotometer.

Determination of Total Dissolved Solids
Conical flasks were washed with distilled water and labelled with respect to the water samples. The initial weights of the conical flasks were determined on a weighing balance. A filter paper was then placed in a funnel and placed into the conical flasks. 10 ml of each water samples were filtered and placed into the oven for 24 hours. The final weights of the conical flasks and dissolved solids were determined on the weighing balance. The difference in weight represented the amount or quantity of dissolved solids in each of the water samples.

Determination of Total Suspended Solids
The initial weight of the filter paper was determined and labelled with respect to each of the water samples. After filtering each of the water samples, the filter paper contained the suspended solids are folded neatly and placed in the oven over night. The final weight of the filter paper containing the suspended solids are determined. The difference in weight represents the quantity of suspended solids contained in each of the water samples.

Determination of Nitrate
Beakers were washed and rinsed with distilled water. The beakers were then oven dried for an hour. 10 ml of each of the water samples were pipetted into each of the beakers with respect to the numbering on the water samples. The samples were then placed into the fume chamber for some time. 2 M sodium hydroxide was prepared. 1ml each of acid was placed in each of the beakers. After 20 minutes, the sodium hydroxide was added. Standards of 0.0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0 were oven dried.

Sodium hydroxide was added to each of the prepared standards to reach 25 ml given either a light or deep yellow coloration. The visible spectrophotometer was used to determine each of the nitrate.

Determination of Calcium and Magnesium
Two separate experiments were conducted simultaneously. One for the determination of calcium only, and calcium and magnesium combined. Using 250 ml beakers, the filtered water samples were lined from 1 to the last sample. 50 ml of distilled water was added to 100ml of water filtered in each sample. 15 ml of ammonia buffer was added to each of the samples in the 250 ml beaker for only the calcium and magnesium combined experiment. 1ml of 5% HAHC was added to all the samples. 1ml of 1% RCN was added to all the samples. 1ml of 4% $K_4Fe(CN)_6$ was added to both experiments. 1ml of triethanolamine was added to all the samples in both experiments. 20 ml of sodium hydroxide was added to the samples for determining calcium only. 0.005 M EDTA was titrated against the calcium and magnesium experiment after adding EBT indicator. 0.005 M EDTA was titrated against calcium only after adding calcium indicator. The difference in the values of the calcium and magnesium experiment and the calcium only experiment gave the values for the Magnesium.

Soil Samplings and Analysis
Some soil properties were studied by collecting soil used by farmers for the production of some vegetables like lettuce and tomato grown in the catchment area. The soil samples were collected from two small scale farmers' fields. Both farmers use the water sources identified within the catchment area for their irrigation. Soil samplings were done at different depths using an auger. The soil samples collected were kept in containers. They were then transported to the laboratory for drying, sieving and analysis. Soil analyses were carried on the soil samples after drying the samples in the laboratory and then sieved in a 2 mm sieve and then analyzed afterwards. The chemical properties that were determined included pH and electrical conductivity. The pH was measured for both the dry and wet seasons using the pH meter and the electrical conductivity was also determined using electrical conductivity meter.

RESULTS AND DISCUSSION

Water Sample Analysis
Water samples were collected from surface water sources in both dry and wet seasons in Mankessim (Baafikrom) and were analyzed for various chemical properties shown in Tab. 1 for the dry season and Tab. 2 for the wet season.
Chemical analysis of surface water sampled in the dry and wet seasons
The results shown in Table 1 are measurements of chemical analysis of surface water from Mankessim sampled in the dry season.
The results show the mean for each parameter analyzed. The chemical analysis of this surface water sampled during the dry season was slightly acidic according to the pH (6.58-6.79) and sodium contents were found to be relatively high. The total dissolved solids (10.0-15.0 mg/L) with a mean value of 9.21 mg/L were found to be within the acceptable limits of irrigation water quality for tomato and onion production [12], [13] and [14]. However, continued use of this water for irrigation, may increase soil alkalinity.

Surface water analysis from Mankessim area during the wet season

The chemical analysis of water samples from surface water sources in Mankessim during the dry season is shown in Tab. 1 in comparison with Tab. 2, where sampling was done in the wet season, the pH of the water in wet season was slightly acidic, with a mean reading of 5.59. The magnesium contents were also slightly elevated above those in the dry season with a mean of 4.29. However, for nitrate, the values were lower (0.52 mg/L) than those analyzed during the dry season (2.06mg/L). This would suggest that the wet season water was slightly acidic compared to the dry season water due to the presence of nitrogen oxides in the precipitate and probably from the dissolved anions from the underlying rocks during percolation [15].

Like water sampled during the dry season, this water also could have no negative effects on soil properties and on crops. Therefore, it can be used for irrigation without any tangible problems [16].

Table 1. Comparison of physicochemical parameters with FAO guidelines in the dry season.

Season		FAO Irrigation Guidelines					DRY SEASON	
Location		Degree of restriction on use				Surface water 1	Surface water 2	Surface water 3
	Parameters	None	Slight-moderate	Severe	Unit	Mean	Mean	Mean
	pH	Normal range 6.5-8			-	6.58	6.58	6.76
	EC	<0.7	0.7-3.0	>3.0	dS/m	0.21	0.192	0.238
	TSS	<50	50-100	>100	mg/l	8.83	6.23	2.75
	TDS	<450	450-2000	>2000	mg/l	10	15	10
	Na	<3	3-9	>9	mg/l	9.09	9.09	9.47
	Ca		0-20	>20	me/l	7.01	5.81	3.46
	Mg		0-5	>5	me/l	4.96	4.61	3.31
	Fe	<0.1	0.1-1.5	>1.5	mg/l	0.38	0.35	0.34
	NO_3	<5	5-30	>30	mg/l	0.31	0.75	0.49
	SAR		0.5-15	>15		3.39	3.32	4.72

Table 2. Comparison of physicochemical parameters with FAO guidelines in the wet season.

Season		FAO Irrigation Guidelines					WET SEASON	
Location		Degree of restriction on use				Surface water 1	Surface water 2	Surface water 3
	Parameters	None	Slight-moderate	Severe	Unit	Mean	Mean	Mean
	pH	Normal range 6.5-8			-	5.75	5.64	5.39
	EC	<0.7	0.7-3.0	>3.0	dS/m	0.171	0.179	0.179
	TSS	<50	50-100	>100	mg/l	1.5	1.75	15.85
	TDS	<450	450-2000	>2000	mg/l	15	35	35
	Na	<3	3-9	>9	mg/l	6.06	7.19	7.58
	Ca		0-20	>20	me/l	2.8	4.6	3.7
	Mg		0-5	>5	me/l	2.91	2.43	2.19
	Fe	<0.1	0.1-1.5	>1.5	mg/l	0.52	1.09	1.73
	NO_3	<5	5-30	>30	mg/l	0.75	2.43	3.01
	SAR		0.5-15	>15		5.66	5.31	5.99

Comparison of the Chemical Properties of the Water Sources

From the results obtained from the three water sources and seasons as recorded in Tab. 1 and Tab. 2, it shows clearly that there were no differences in EC, TDS, and TSS data, in both seasons. However, some of the parameters had differences in the wet season but not in dry season, which includes pH, Fe, and NO_3 in the dry season while other parameters had differences dry seasons for example, TSS and Ca. This could be a reflection of water source origin as influenced by the weathering of parent materials, and differences in seasonal depositions from the atmosphere [17].

Comparison of the Sodium Absorption Ratio of the water sources for wet and dry Season.

The SAR is an indicator of the amount of sodium (Na) in the water relative to calcium (Ca) and magnesium (Mg). A situation that hampers permeability affects the fertility and it reduces the crop yield. The dry season water samples analyzed had a lower Sodium Absorption Ratio compared to the wet season samples. The maximum sodium absorption ratio recorded in the dry season samples was the surface water 3 giving SAR of 4.72 and the minimum being surface water 2 which was 3.32. Also, the minimum Sodium Absorption Ratio recorded for the wet season was surface water 2 giving SAR of 5.31 and the maximum being surface water 3 which is 5.99. Even though the SARs for both the dry and wet seasons fell within the acceptable FAO range, water will be readily available to the plant roots when irrigated in the dry season than the wet season. This is because of the high sodium content in the wet season compared to the dry season which, its effect may manifold as specific ion toxicity to sodium sensitive plants, impaired soil drainage and plant nutrition imbalance or deficiencies in the plants as stated by Hussain [18]. When irrigated in the wet season, there is an increase in the exchangeable sodium content on soil exchange complex and disperses the soil more rapidly affecting crop and yield. There is also the possibility of high soil pH resulting in lock of phosphates, iron and other micronutrients as well as dispersion of clay and slit particles in the soil which may collapse the soil structure and blocking soil pores thereby the resulting effect on reducing the effectiveness of irrigation.

Comparison of the Total Water Salinity of the water sources for wet and dry Seasons

From the results, the total water salinity of the surface water sources for both the dry (Fig. 2) and wet seasons (Fig. 3) were within the FAO acceptable range since salinity is analyzed using either the electrical conductivity or the Total dissolved solids [18]. Irrigation during the wet season has salinity content compared to the dry season. The maximum electrical conduction and Total dissolved solids for the dry season are 0.238 and 15 respectively while those of the wet season are 0.59 and 35 respectively. This indicates that the salinity contents of the surface water sources are higher during the wet season compared to the dry season. The soil salinity increases in direct proportion to the salinity of irrigation water and the depth of water applied, hence the plant growth reduces during the wet season as compared to the dry season.

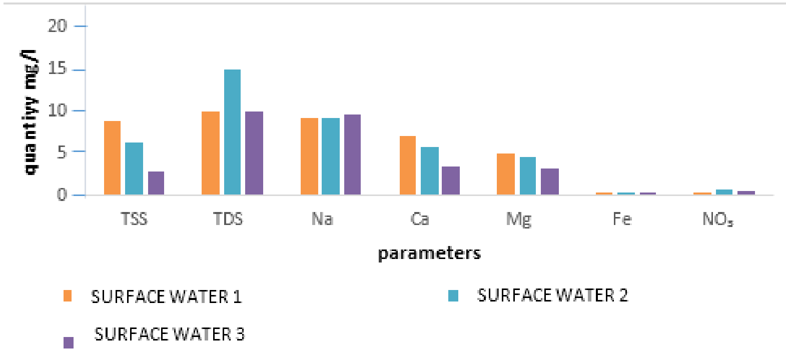

Figure 2. Water quality analysis from surface water sources in Mankessim during the dry season

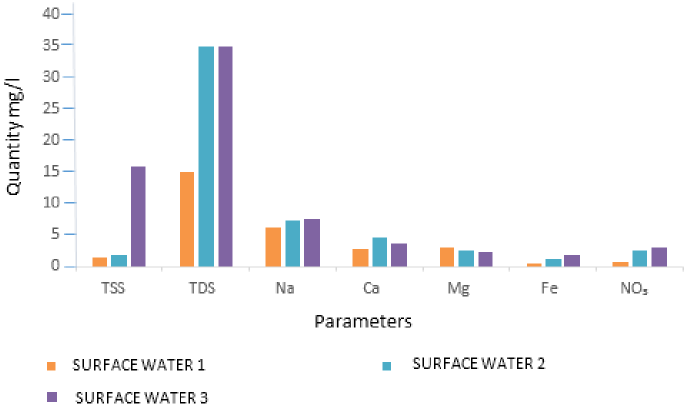

Figure 3. Water quality analysis from surface water sources in Mankessim during the wet season

Some chemical properties of soils sampled in dry and wet seasons from farms using surface water sources for irrigation (Mankessim)

The soil analysis was carried out on both the irrigated and non-irrigated farms for the wet and dry seasons as shown in Tab. 3. The pH of soils sampled from the irrigated farm in both the wet and dry seasons gave no significant differences which is 6.74 and 6.50 respectively which were both weak acidic soils. With the non-irrigated farms, there was significant difference between the wet and dry seasons which are 6.73 (slightly acidic) and 7.3 (neutral) respectively. Comparing the irrigated and non-irrigated soil analysis on pH, the wet season gave slight difference while that of the dry season gave significant difference. The electrical conductivity of the soil extract was extremely low with values lying between 0.14 and 0.51 dS/m for irrigated and non-irrigated farms respectively in the wet seasons. The dry season also had extremely low with values 0.09 and 0.34 for non-irrigated and irrigated farms respectively, which indicates the absence of a negative effect by (lack of danger) of dissolved solids in this soil.

Table 3. Chemical analysis of soil sampled in wet and dry season from farms which used surface water sourcesfor irrigation (Mankessim).

SEASON		DRY SEASON		FAO VALUES			WET SEASON	
		Irrigated area	Non-irrigated area				Irrigated area	Non-irrigated area
Location	Parameters	Mean	Mean	Normal	Moderate	Severe	Mean	Mean
	pH dS/m	6.5	7.3	5.5- 7.0 8.0	>9.5		6.74	6.73
	EC ms/l	0.34	0.09	0-2	4-15	>15	0.14	0.51

From the soil samples analyzed, the pH of the non-irrigated area for the dry season was recorded as 7.3 indicating that it was alkaline in nature while that of the irrigated area was within the acceptable FAO value which is 6.5. For the wet season, the values recorded for both the irrigated and non-irrigated areas were within the accepted FAO values and these were 6.74 and 6.73 respectively. These results indicate that the plant will not be affected negatively with regard to the pH of the soil after irrigating in both the dry and wet seasons. Also, the electrical conductivity values recorded in the soil were low and will have less influence on the salinity of the soil.

CONCLUSION

From the results of this study, the pH of the water in the dry season for all the surface water sources were slightly acidic and could be used for irrigation while that of the wet season were almost severe but could be adequately used for irrigation. However, continuous use of this water during the wet season could affect the system or equipment used for irrigation, uniformity, crop growth and yield. The pH of the water entering the distribution system must be controlled to minimize the corrosion of water mains and pipes in the spray tube systems. The optimum pH will vary in different supplies according to the composition of the water and the nature of the construction materials used in the distribution system, but is often in the range 5.5 – 9.5. Extreme pH values can result from accidental spills, treatment breakdowns, and insufficiently cured cement mortar pipe linings. Also, the sodium absorption ratio values which influences the infiltration of water into the soil for the reach of plant root were all normal thus the plant root could have access to the irrigated water. The electrical conductivity level for all the water sources and soil parameters measured were low and thus could have less or no effect on the salinity of the water which could be detrimental to irrigation tubes and pipes. The soil samples for the wet season were slightly acidic and favorable for crop growth while those of the dry season were normal in terms of their acidity. This indicates that the water was favorable for irrigating crops within the catchment area and will not inhibit the irrigation system used.

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OCENA KVALITETA VODE ZA NAVODNJAVANJE I ODABRANI PARAMETRI ZEMLJIŠTA ZA MANKESSIM OBLAST, GANA

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Apstrakt: Navodnjavanje je postao veoma kritični faktor u postizanju određenog kvaliteta proizvodnje useva tokom cele godine. Cilj ovog istraživačkog rada bio je procena kvaliteta vode za navodnjavanje za određene parametre zemljišta za oblast navodnjavanja Mankessim (Gana), koja se koristi za navodnjavanje svih vrsta useva u ovoj oblasti i okolini.
Podaci za studiju prikupljeni su iz dve oblasti: uzoraka vode i zemljišta. Uzorci vode su prikupljeni iz tri različita izvora površinske vode u okviru oblasti za sušnu i za vlažnu sezonu. Sakupljeno je devet (9) različitih uzoraka za svaku sezonu, tri (3) uzorka za svaki izvor površinske vode.
Takođe, sakupljeno je šest (6) različitih uzoraka zemljišta za svaku sezonu. Uzorci zemljišta su prikupljeni sa navodnjavanog i nenavodnjavanog poljoprivrednog zemljišta.
Rezultati studije su pokazali da se izvori vode (površinski), nisu značajno razlikovali po osobinama jedni od drugih u poređenju sušnih i vlažnih sezona i da su njihove hemijske vrednosti bile u granicama prihvatljivim za navodnjavanje i biljnu proizvodnju.
Koncentracije vrednosti (Na, Ca, Mg, EC i TDS) bile su značajno unutar dozvoljenih granica kod upotrebe vode za useve.

Ključne reči: *Kvalitet vode za navodnjavanje, salinitet, ukupne rastvorene čvrste materije.*

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